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SIMPLE AND CHOICE REACTION TIME IN A SECONDARY TASK UNDER VARIED STIMULUS MODALITY PROBABILITIES

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Most investigations of attention and attention allocation have been limited to assessments of attention shifting among stimuli simultaneously presented within a single sensory modality. The construct of attention, however, is generally conceptualized as the process which determines the selection of

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sensory information from all potential sources, among all potential modalities. Although limited in relevance to more "real-world", high demand task situations, many of the findings and interpretations from single modality attention studies provide an important theoretical basis for performance assessment in complex task environments requiring multimodal processing. The objective of the present research was to directly assess attention allocation in tasks requiring both visual and auditory information processing. In this vein, the present effort sought to generalize previous findings which demonstrated that when the uncertainty of a stimulus modality's relevance is reduced by providing subjects with a cue prior to each discrete trial, simple reaction times decrease. In the present study, modality uncertainty was reduced by experimentally manipulating the probability of stimulus occurrence within a given modality. Furthermore, responding in the present experiment required choice as well as simple reaction, and the responses were made jointly with the continuous execution of a three-axis, compensatory tracking task.

As expected, simple and choice reaction times to auditory signals were faster than were those to visual signals. Moreover, the margin favoring faster reactions to tones was exaggerated when the probability was high that the relevant modality was auditory, but only under choice reaction conditions.

Further research is required to determine the sensitivity of secondary attentional investment to the effects of primary and secondary task response complexity, signal presentation rate and intensity, as well as to that of other task and environmental variables known to influence performance in high demand settings.

SUMMARY PAGE

THE PROBLEM

Most investigations of attention and attention allocation have been limited to assessments of attention shifting among stimuli simultaneously presented within a single sensory modality. The construct of attention, however, is generally conceptualized as the process which determines the selection of sensory information from all potential sources, among all potential modalities. Although limited in relevance to more "real-world", high demand task situations, many of the findings and interpretations from single modality attention studies provide an important theoretical basis for performance assessment in complex task environments requiring multimodal processing. The objective of the present research was to directly assess attention allocation in tasks requiring both visual and auditory information processing. In this vein, the present effort sought to generalize previous findings which demonstrated that when the uncertainty of a stimulus modality's relevance is reduced by providing subjects with a cue prior to each discrete trial, simple reaction times decrease. In the present study, modality uncertainty was reduced by experimentally manipulating the probability of stimulus occurrence within a given modality. Furthermore, responding in the present experiment required choice as well as simple reaction, and the responses were made jointly with the continuous execution of a three-axis, compensatory tracking task.

RESULTS

As expected, simple and choice reaction times to auditory signals were faster than were those to visual signals. Moreover, the margin favoring faster reactions to tones was exaggerated when the probability was high that the relevant modality was auditory, but only under choice reaction conditions.

RECOMMENDATIONS

Further research is required to determine the sensitivity of secondary attentional investment to the effects of primary and secondary task response complexity, signal presentation rate and intensity, as well as to that of other task and environmental variables known to influence performance in high demand settings.

INTRODUCTION

Modern tactical aviation weapon systems impose extreme demands on the limited information processing resources of the human operator. Demands derive from an extensive array of visual and auditory information displays and require highly coordinated continuous and discrete responding. To function effectively in the high speed aviation environment, an operator must be able to anticipate events properly and direct attention appropriately and economically to various tasks under time-constrained conditions. In such situations, decision speed and accuracy are critical determinants of success. Central to an improved understanding and prediction of performance in these contexts are considerations of variables that can influence attention allocation to multiple stimuli and overall information processing efficiency.

The formulation of a useful model of attentional behavior, and of information processing in general, has been the goal of extensive research over the years (4). As Boulter (1) pointed out, however, these studies have concentrated primarily on attentional shifting within a single sensory modality. He further noted that most, if not all, conceptualizations of attention hold it to be a process which in some way determines the selection of sensory information from among all modalities. It is somewhat surprising, therefore, that the research community has concentrated so heavily on studies of attention to multiple stimuli presented simultaneously within a single modality. According to Boulter, intermodality attention research represents a much more promising avenue for future theoretical work as (a) the notion of attention as a central selective process can be addressed from a number of new perspectives, and (b) the relative demands of intermodal vs. intramodal differentiation upon limited attention capacity may be assessed. From an applied perspective, moreover, the methods and results of intermodality research are clearly more relevant to performance assessment and prediction in complex, high demand settings.

Boulter (1) demonstrated the robustness of the intermodality paradigm in a study designed to test contemporary assumptions about the selective aspects of attention. Specifically, a signal was presented to subjects via either the visual, auditory, or tactile modality. Upon presentation of a signal, the subject immediately depressed a response button. The simple a-reactions (2) were non-discriminative with regard to stimulus modality. However, the predictability of the relevant modality was varied by providing a cue light or lights immediately prior to each signal presentation. A different cue light was associated with each modality. If prior to stimulus onset one light was illuminated, the subject knew with certainty what stimulus would follow. If two lights were illuminated, the subject knew that the stimulus would be presented in one or the other of the two modalities, and so on for three lights. Boulter found that simple reaction time varied directly with the manipulated uncertainty about the stimulus modality which was likely to contain the stimulus.

Although important, Boulter's (1) results are limited to task environments in which only simple responses to discrete stimuli are required and in which the probability of a modality relevance is determined immediately prior to each trial. The present study sought to extend Boulter's findings to task situations in which more complex choice reaction is required and where stimulus modality probability is determined as a function of the posterior, relative frequencies of stimulus occurrences within each modality over all prior trials. Rather than providing subjects with foreknowledge of the relevant modality, this study adopted the method of manipulating modality probability by varying the frequency of stimulus presentation across modalities during the reaction time task. In this way, the effects of modality probability, if any, on reaction time, may be assessed independently of the effects of precuing. Furthermore, to emulate more closely the high workload conditions of interest, the choice reaction time task was performed jointly with a dual-tracking, psychomotor loading task.

METHOD

SUBJECTS

Eight male student naval aviators awaiting flight training volunteered to participate in this study. All reported being right-handed and having normal vision and hearing. Ages ranged from 21 to 24 yr.

APPARATUS

Psychomotor Loading Task. The psychomotor loading task was provided by a Systems Research Laboratories, Inc. Model 1017 Psychomotor Test Device (PTD) Console. By means of a single two-axis, floor-mounted, spring-loaded, self-centering joystick, the subject maintained a rate-controlled cursor at the intersection of horizontal and vertical lines that defined the center of a 19-cm by 25-cm CRT screen. Simultaneously, the subject employed spring-loaded, self-centering, reciprocating foot pedals to center a rate-controlled cursor that moved horizontally on the CRT screen. The cursor was centered on the vertical line that defined the center of the CRT display at a point 2.2-cm from the bottom of the screen.

Auditory Reaction Time Task. Stimuli for this task were generated under computer control by a Krohn Hite Model 4031R programmable oscillator. A 500-Hz oscillator-generated sinusoidal signal was transmitted to a Tapco Model CP-120 dual-channel power amplifier and to the earphones of a Telex CS-85 headset with a resultant output of 70dB SPL re 20 μ N/m^2.

Visual Reaction Time Task. Stimuli for this task consisted of two 6-v incandescent lamps mounted in a smoke-tinted plexiglass panel which was superimposed over the CRT screen of the PTD. One lamp was located 2.2-cm to the left of and at the vertical midpoint of the CRT screen. The other was located at the corresponding point on the right.

Response switches for the SRT and CRT tasks were mounted on the left front panel of the PTD console. The subject was required to depress a switch only after the presentation of a stimulus. In all cases the subject used the left hand for reaction time responses and the right hand for tracking. The subject was instructed (a) to depress the left-mounted button if the stimulus was the light to the left of the CRT screen or a tone presented to the left ear, and (b) to depress the right-mounted button if the stimulus was the light to the right of the CRT screen or a tone presented to the right ear. The subject actuated and maintained the depression of a momentary switch located in a home position between the two response buttons following each response.

PROCEDURE

Each experimental session was divided into two blocks of trials separated by a 5-min rest period. Each block was divided into two, 5-min test conditions during which subjects performed both the reaction time task and the dual compensatory tracking tasks. For four subjects the first block of trials was devoted to two SRT conditions, while the second block was devoted to two CRT conditions. For the remaining four subjects, the opposite order was employed. The two SRT conditions differed in that in one condition a light was four times as likely to occur on any one trial as was a tone, while in the other condition a tone was four times as likely to occur as was a light. Identical stimulus presentation relationships were employed for CRT conditions. Within each block, two subjects received the high light probability condition first. Two subjects received the high tone probability condition first.

During each 5-min test condition, a total of 75 stimulus presentations occurred at a rate of 15 presentations per minute. In the high tone probability condition, 60 stimuli were tones and 15 stimuli were lights. In the high light probability condition, the opposite ratio was employed. Subjects wre not informed of these ratios, but rather were instructed to press the appropriate response button as quickly as possible whether a tone or light occurred. In addition, subjects were instructed to execute these responses while concurrently performing as accurately as possible on the dual tracking tasks.

Prior to the start of each experimental trial block, subjects were afforded five minutes of practice on the tracking tasks, followed by five minutes of practice on the reaction time task of the type (SRT or CRT) that would be subsequently administered for testing. During the practice session, stimuli were presented at the rate of 10 per minute and tones and lights were equally probable. In both practice and test SRT conditions, only the light on the left side of the CRT screen was used and only the left earphone was used to present the tone. In both practice and test SRT conditions, the light on the left of the CRT screen was as likely to be illuminated as that on the right and the tone was as likely to be presented to the left ear as to the right. Total practice and test time was approximately one hour.

RESULTS AND DISCUSSION

PSYCHOMOTOR LOADING TASK

An unambiguious analysis of the effects of stimulus modality probability must be preceded by an assessment of the relationship between observed variation in psychomotor performance and the manipulated variation in stimulus modality probability. To that end, root-mean-square error in tracking along the three axes was summed over the 5-min test session associated with each stimulus modality probability and subjected to a two-way, repeated conditions, variance analysis. No significant differences in tracking performance as a function of modality probability ($F < 1.00$) or as a function of task complexity (SRT vs CRT; $F < 1.00$) were found. The statistical interaction between modality probability and task complexity was also found to be nonsignificant ($F < 1.00$)

SIMPLE REACTION TIME

Response times to tones and to lights, respectively, were averaged across subjects for each modality probability and a two-factor completely within-subjects variance analysis was applied. Potential sources of variance were stimulus modality (auditory vs visual), modality probability and the modality x probability interaction. The analysis revealed a significant effect for stimulus modality, [$F(1,7) = 74.30$; $p < .001$]. As indicated in Figure 1, responding to tones was more rapid than was responding to lights. The effect of modality probability was not reliable, however [$F(1,7 = 1.52$; $p > .25$], nor was the interaction of modality and probability effects [$F(1,7) = 5.20$; $p < .10$]. Accuracy for all subjects in all conditions exceeded 98 percent.

CHOICE REACTION TIME

Response times to tones and to lights respectively, were averaged, as for SRT, across subjects for each modality probability and subjected to a two-factor, within subjects variance analysis. The procedure revealed that (a) responses to tones were faster than to light signals, [$F(1,7) = 30.96$; $p < .001$], (b) response time, collapsed across modalities, was unaffected by modality probability, [$F(1,7) = 1.17$, $p > .25$] and that (c) the interaction between modality and probability was statistically significant [$F(1,7) = 12.16$, $p < .025$]. Accuracy scores were, as for SRT, nearly perfect across all conditions.

Figure 2 portrays the main effect for modality, as well as the interaction of probability and modality effects. This interaction implies that the auditory reaction time which is typically faster than visual reaction time (3) is further enhanced when the probability is high that the next signal will be a tone.

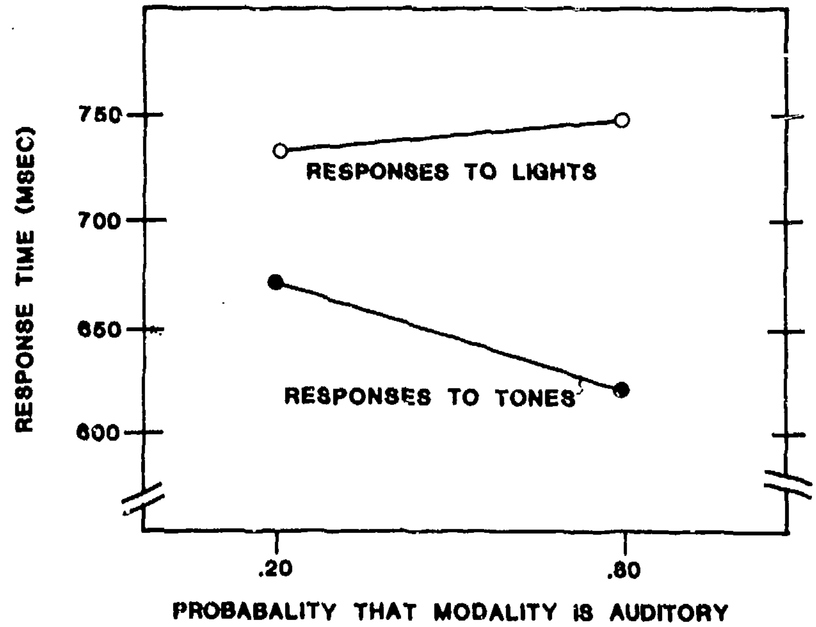

Figure 1. Response curves depict faster simple reaction times when responding to auditory than to visual stimuli.

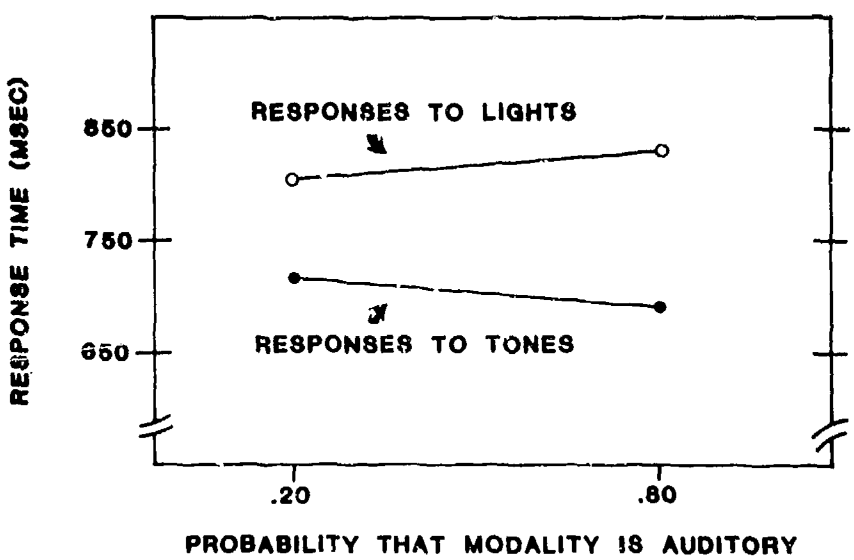

Figure 2. Curves portray significantly faster choice reaction to auditory signals, and an exaggeration of this auditory dominance when the probability is high that a signal will be auditory.

It is not unreasonable to assume that greater attentional reserve is invested in the modality for which the likelihood of stimulus presentation is high and that the greater the attentional investment, the faster the reaction time. This is precisely what Boulter (1) found when the relevant modality was cued in a very unsubtle fashion. The results of the present study indicate that choice reaction time is systematically related to the relative frequencies with which stimuli are presented via alternative modalities. Regardless of the manner inn which subjects become aware of differences in stimulus presentation frequencies across modalities, those differences appear to influence selective attention and decrease reaction time to stimuli presented within the more probable modality.

Typical theoretical conceptualizations of attention allocation emphasize the selective direction of attention to stimuli presented in one modality, or from one source, to the exclusion of others. The present results provide new evidence concerning the effects of task variables when attention must be shared between the demands of simultaneously competing tasks and between modalities in one of the tasks. Similar studies are required to determine the sensitivity of secondary attentional investment to the effects of primary and secondary task response complexity, signal presentation rate and intensity, as well as to that of other task and environmental variables known to influence performance in high demand settings. As suggested by Boulter (1), the data from such studies will extend the basis for present theories of attention. Of perhaps greater importance, however, these data will facilitate predictions of performance in complex task structures that emulate the demands of actual task environments.

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